Resistive Force of Friction

by Ron Kurtus (revised 8 April 2005)

Friction is a resistance to motion that is opposite the direction of travel. It is caused when two surfaces are in contact. Since friction acts to slow down a moving object, it is called a resistive force. This is different than active forces that cause objects to accelerate or change direction.

(See Forces and Work Against a Resistive Force for background material.)

Friction is mainly caused by surface roughness. The classic law of friction states that friction is the product of a coefficient and a force. The main two types of friction--static and kinetic--create different amounts of resistance for the same objects.

Questions you may have about friction include:

- What causes friction?
- What is the Friction Law?
- What are the different types of friction?

This lesson will answer those questions. There is a mini-quiz at the end of the lesson.

Causes of friction

Friction is caused by the roughness of the materials rubbing against each other, deformations in the materials, and a molecular attraction between materials.

Surfaces not completely smooth

Most friction results because the surfaces of materials being rubbed together are not completely smooth. If you looked at what seems to be a smooth surface under a microscope, you would see bumps, hills and valleys that would interfere with sliding motion. Of course, the rougher the surface, the more the friction.

If both surfaces become ultra-smooth and flat, the friction from surface roughness becomes negligible, but then friction from molecular attraction comes into play, often becoming greater than the normal friction.

Deformations

Soft materials will deform when under pressure. This also increased the

resistance to motion. For example, when you stand on a rug, you sink in slightly, which causes resistance when you try to drag your feet along the rug's surface. Another example is how rubber tires flatten out at the area on contact with the road.

When materials deform, you must "plow" through to move, thus creating a resistive force.

Molecular attraction

There is another factor in friction, and that is stickiness caused by molecular attraction. This was mentioned above where surfaces are so smooth that the materials stick together due to molecular forces.

Soft rubber is an example of a material that can have this type of friction. This factor is usually seen in rolling friction. The stickiness will create a resistance to any motion. Although this force is the smallest, it still can be a factor when the other causes of friction are low.

Friction law

The classic Friction Law applies to trying to slide one object along the surface of another. It is the most common form of friction. This law states that the force required to overcome friction for two objects or materials pushing against each other equals the coefficient of friction for the two materials times the perpendicular or normal force pushing the objects together. The equation is:

$$F_r = f_r * N$$

where F_r = the resistive force of friction, **u** = the coefficient of friction, and **N** = the normal or perpendicular force pushing the two objects together. F_r and **N** are measured in units of force, which are pounds or newtons.

The coefficient of friction is a decimal number that is mainly determined by the comparative roughness of the two materials. (See Determining the Coefficient of Friction for more information.)

For example, if the coefficient of friction (f_r) for automobile disc brakes is 1.5 and the force pushing the pad and the disc together (**N**) is 500 pounds, the braking force F_r = 750 pounds.

Weight as force

In some cases, the normal force **N** can be caused by gravity instead of some applied pressure. This would be in the situations where you want to slide a heavy object across a surface. In such cases, the friction equation becomes:

$$F_r = f_r * W$$

where **W** is the weight of the object.

Thus if a box weighs 100 pounds and the coefficient of friction between it and the ground is 0.7, then the force required to push the box along the floor is 70 pounds. Likewise if a box weighs 500 newtons is placed on ice with a coefficient of friction of only 0.001, then it would only take 0.5 newtons to move the box.

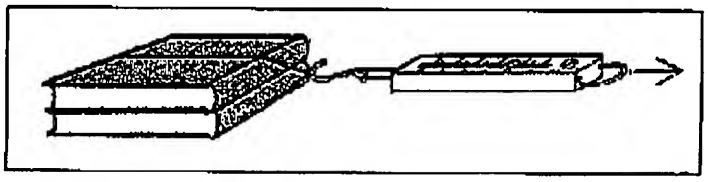
Verify the law

Just as a scale can be used to measure the weight of an object, it can also be used to measure the force required to overcome friction. You can place an object such as a book on a table and measure the force required to move that book.

Double the weight

Then, if you double the weight--like using two books--the force required to move the books will also double.

(Note that the push or pull must be parallel to the ground. If you pull up slightly when trying to move the objects, the force between the surfaces is reduced and the measurement is not correct.)



Two books require twice the force to pull them than one book

Independent of area

The most important thing about the friction law or equation is that friction is independent of the surface area in contact. In other words, it is just as difficult to move a 1 cm square object as a 1-meter square object, if they both are pressed to the surface with the same amount of force.

For example, it would take the same force to move a heavy desk across a wooden floor if the desk was on its side or if the desk was on its legs, provided the coefficient of friction was the same.

Not intuitive

This is not intuitive. You would think that there is more friction when the surfaces are larger. But the friction law states otherwise. You can verify this with experiments.

Some exceptions

The fact that friction is independent of the areas in contact applies to the common friction situations. The cases where surfaces deform or there is molecular attraction, surface area sometimes comes into play.

Types of friction

There are two main types of friction: static and kinetic. Static friction is the amount of resistance to motion when an object is static or not moving. Kinetic friction is the resistance on a moving object.

Kinetic friction is further classified as sliding or rolling friction. Kinetic friction plays a small part in air or water resistance.

Static friction

Did you ever notice how hard it is to move a heavy object, but once you start it sliding, it seems to move easier? It acts like it is almost stuck to to floor until you get it moving.

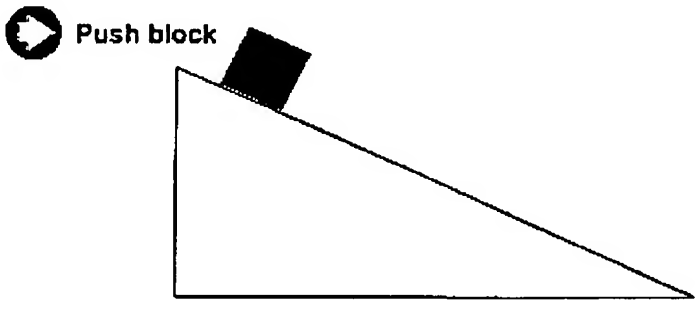
Although you need to overcome the inertia of the heavy object, much of the effort needed is due to the fact that static friction is usually greater than sliding or kinetic friction. Static friction is caused by a combination of the resistance due to the roughness of the surface and the molecular attractions trying to hold the surfaces together.

Kinetic friction

Once an object is moving, the amount of friction is less than when it was standing still. Sliding friction is a form of kinetic friction. Most of the friction is cause by the roughness of the two surfaces.

Difference between them

Click on the arrow in the picture below to see what happens when you push on the block.



***Static friction* holds the block in place on the ramp. Give it a push.**

Bumps over when sliding

The reason sliding friction is less is because, once the object is moving, it is bumping over the microscopic humps or roughness between the two surfaces.

Rolling friction

When a wheel rolls, there is friction at the point of contact with the ground. Otherwise, it would simply slide along the surface. This type of friction is primarily caused by the stickiness of the surfaces. That is why a smooth rubber tire will slide less than an rough metal wheel.

Rolling friction is highly complex and is an important factor in automobile tires. *(See Rolling Friction for more information.)*

Fluid resistance

The kinetic friction of a fluid along the surface of an object that is moving through the air, water or other fluid is very small. That is why fluids such as oil are used as lubricants.

Don't confuse fluid friction with air or water resistance. That is caused by having to move the fluid out of the way in order to travel through it.

Air or water resistance is affected by the streamlining of the object. Air friction is affected by the surface roughness of the object.

In conclusion

Friction is an important resistive force that will slow down and stop objects from moving. The equation for friction is $F_r = f_r * W$. There are two major types of friction: static and kinetic.

Reader Questions and Feedback | Where can you go from here?

Don't let the resistive forces of others slow you down

Resources

The following resources provide information on this subject:

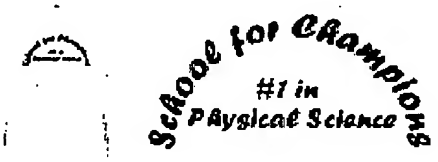
Websites

Physical Science Resources

Books

Miscellaneous

School for Champions brand products - Visit our **online store** for t-shirts, caps, mugs and other products related to Physical Science.



One of the many designs and products

Mini-quiz to check your understanding

1. How does surface roughness affect friction?

[a.] The tiny bumps make sliding motion more difficult

[b.] Roughness prevents any motion

[c.] Surface roughens causes molecular effects

2. If the force to slide one box on the floor is 10 pounds and you stack two other boxes of the same weight on top, what force is needed to slide them?

[a.] 10 pounds, because friction is independent of weight

[b.] 20 pounds, because you added two boxes

[c.] 30 pounds, because friction is proportional to weight

3. Which is greater: static or kinetic friction?

[a.] Static, because of additional friction forces

[b.] Kinetic, because it is harder to keep the object moving

[c.] They are the same, if the weight is the same

If you got all three correct, you are on your way to becoming a champion in science. If you had problems, you had better look over the material again.

What do you think?

Do you have any questions, comments, or opinions on this subject? If so, send an email with your feedback. I will try to get back to you as soon as possible.

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